

Sizing Intakes

Design Manual

Chapter 4

Drainage

Originally Issued: 09-01-95

At this stage in the design process, the designer has normally determined an intake's location with a fairly high degree of certainty. What remains is to decide how large the intake should be. This decision is based on how much water must be dealt with (the rate of flow, Q) and, in some cases, how much encroachment of water onto the driving lanes can be tolerated (based on Table 1 in Section 4A-5). This section of the manual describes the standard intakes used by the Iowa DOT and how to adjust for non-standard intakes. It also provides rules for deciding which intakes to use (based on their capacities).

General Rules for Sizing and Locating Intakes

The designer normally chooses the size of an intake with the goal of intercepting 85% to 90% of the water flowing past the intake's location. Intercepting 100% of the water is not economical at most locations because it takes 33% of the curb opening to intercept the last 15% of the water (shown in Figure 1). Nonetheless, the designer should observe the following minimums when choosing an intake:

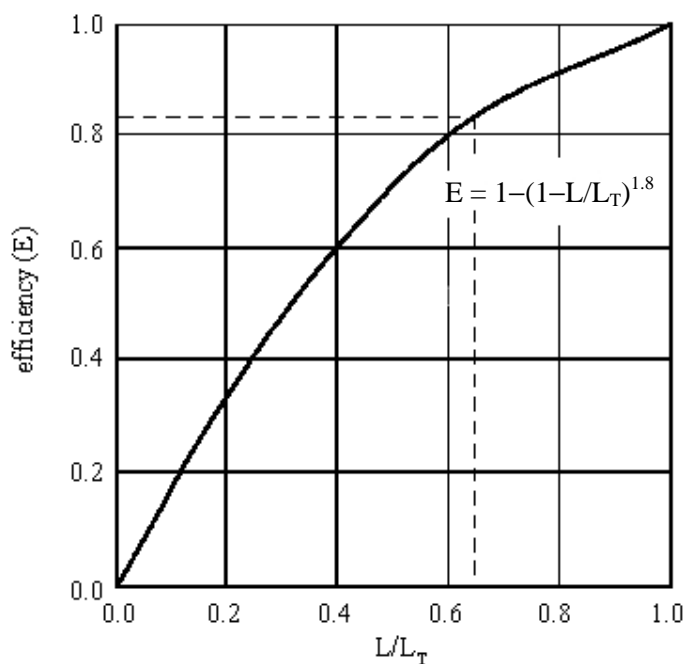


Figure 1: Inlet interception efficiency for curb-opening and slotted-drain intakes,¹ where L is the curb opening length and L_T is the curb opening length required to intercept 100% of the gutter flow.

¹ FHWA, "Drainage of Highway Pavements," *Hydraulic Engineering Circular No. 12* (March 1984).

- Curb opening type intakes should intercept a minimum of 85% of the water
- Grate type intakes should intercept a minimum of 78% of the water

If an intake intercepts less than the minimum, a longer opening or additional intakes should be used. Additionally, intakes at the low points of sag vertical curves and at the ends of curb and gutter sections should always intercept 100% of the water.

Capacities for Standard Intakes

Standard Iowa DOT intakes are shown in Standard Road Plans RA-40 to RA-48 and RA-60 to RA-70. Table 1 indicates the size or “length of opening” for each. To determine what percentage of a flow an intake will capture, the designer uses Figure 2, 3, or 4. The following indicate which figure to use with each standard intake:

- Figure 2: RA-40 and RA-41 intakes
- Figure 3: RA-43 intake and RA-41 intake with RA-42 extension
- Figure 4: RA-70 intake and RA-41 with two RA-42 extensions

To use the figures, find the spread, w , (calculated in Section 4A-5) on the bottom left of the figure and draw a vertical line to intersect the longitudinal grade of the gutter, S_L . Then draw a horizontal line across the chart to the gutter cross slope, S_x . At this intersection point, draw a vertical line to the top of the figure and read the inlet interception rate (Q/Q_0). This quantity is the ratio of water intercepted by the intake divided by the total flow of water.

Table 1: Standard intakes.

type	length of opening (L)	
	English	metric
RA-40	4'	1.2 m
RA-41	4'	1.2 m
RA-41 with RA-42 extension	9' 2''	2.75 m
RA-41 with two RA-42 extensions	14' 4''	4.25 m
RA-43	8'	2.4 m
RA-70	12'–18'	3.6 m–5.4 m

Capacities for Other Intakes

If the RA-41 with or without extensions, the RA-70 intake (where L is variable) or a nonstandard intake is used, the designer will normally need to make adjustments to Figure 2, 3, or 4 because the dimensions will often be different than those shown at the bottom of the figure. These dimensions are illustrated in Figure 5. They are the length of the intake's opening (L), the width of special shaping around the intake (W), and the depth of the intake depression (a).

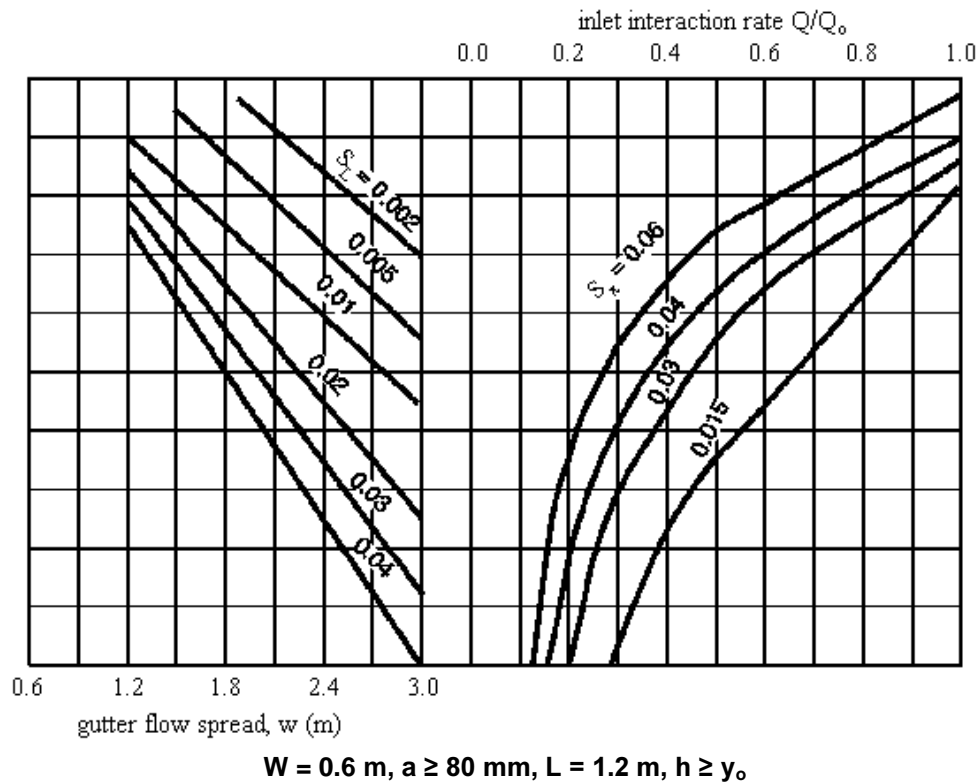
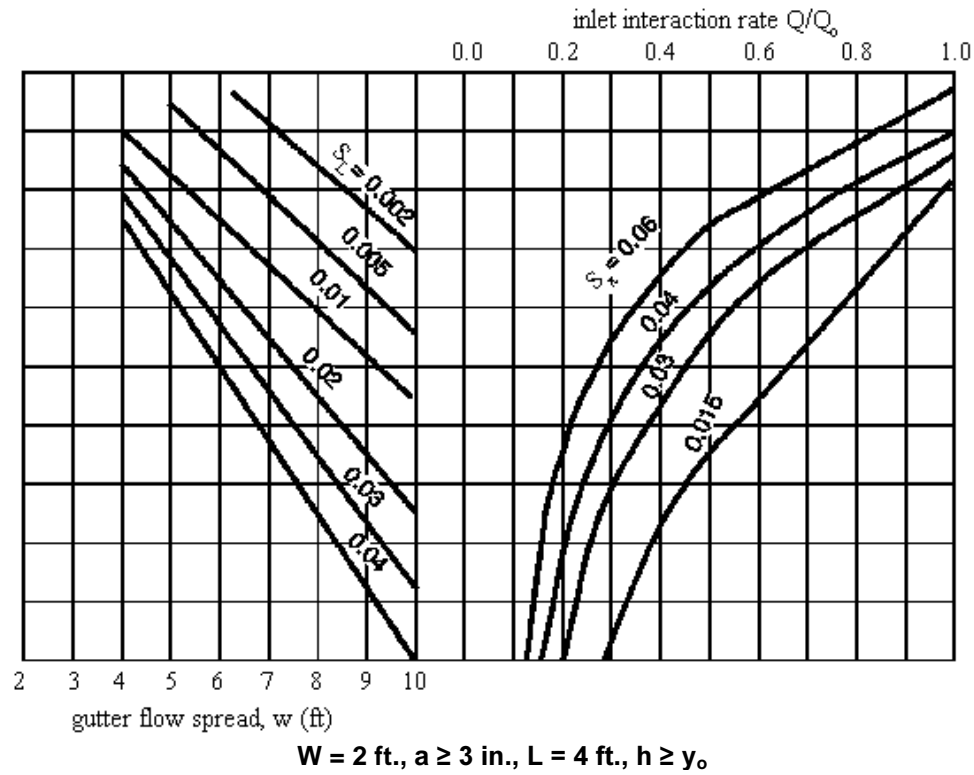
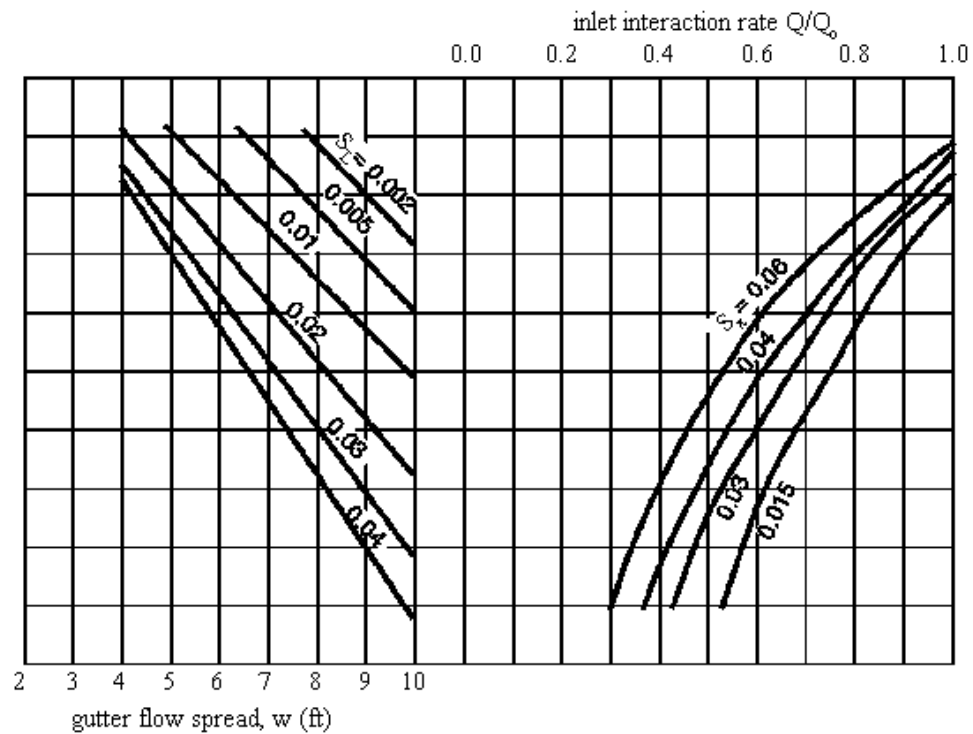
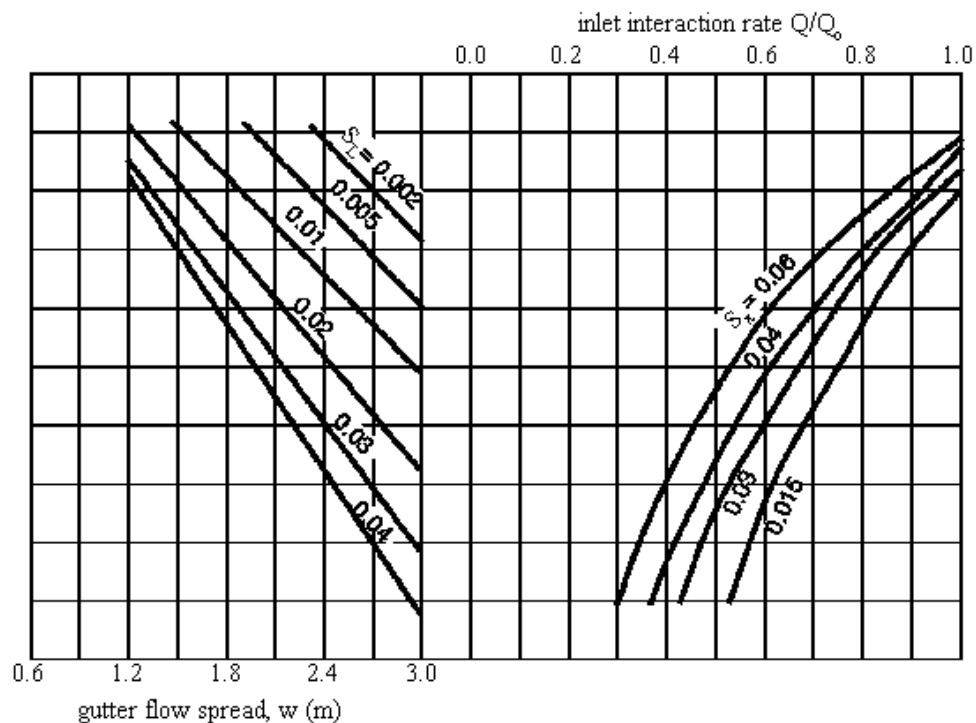


Figure 2: Capacity of curb-opening inlet on constant grade (for use with the RA-40 and RA-41 intakes).²

² Iowa State University, Engineering Extension (Civil Engineering), *Urban Drainage Short Course for Iowa Department of Transportation Highway Division* (November 1979).

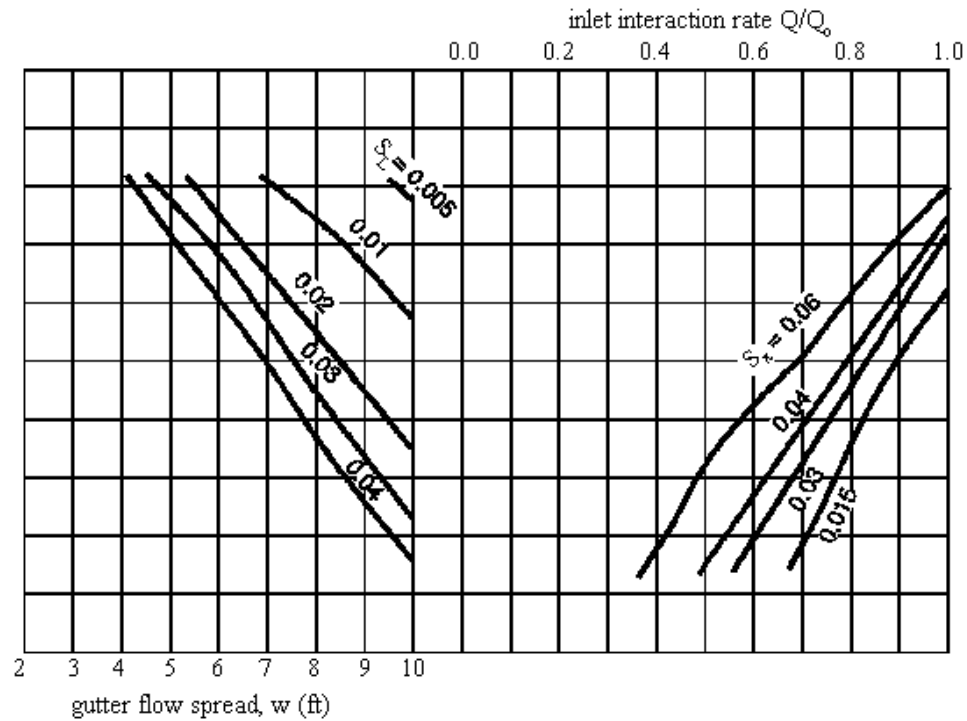


$$W = 2 \text{ ft.}, a \geq 3 \text{ in.}, L = 8 \text{ ft.}, h \geq y_0$$

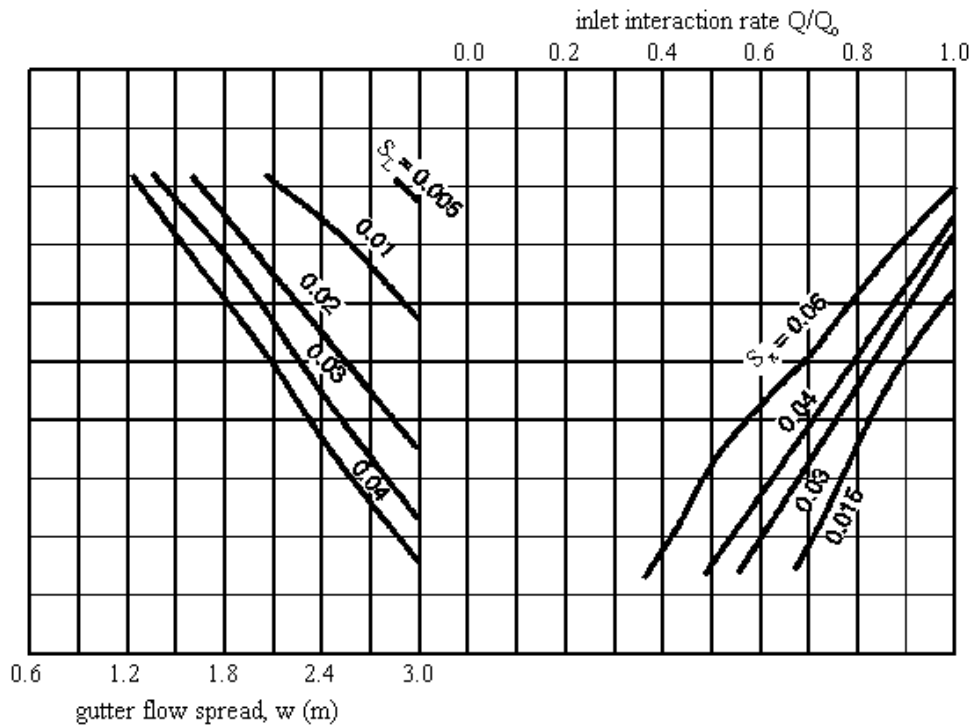


$$W = 0.6 \text{ m}, a \geq 80 \text{ mm}, L = 2.4 \text{ m}, h \geq y_0$$

Figure 3: Capacity of curb-opening inlet on constant grade (for use with the RA-43 intake and the RA-41 intake with an RA-42 extension).²



$W = 2 \text{ ft.}, a \geq 3 \text{ in.}, L = 12 \text{ ft.}, h \geq y_0$



$W = 0.6 \text{ m}, a \geq 80 \text{ mm}, L = 3.6 \text{ m}, h \geq y_0$

Figure 4: Capacity of curb-opening inlet on constant grade (for use with the RA-70 intake and the RA-41 intake with two RA-42 extensions).²

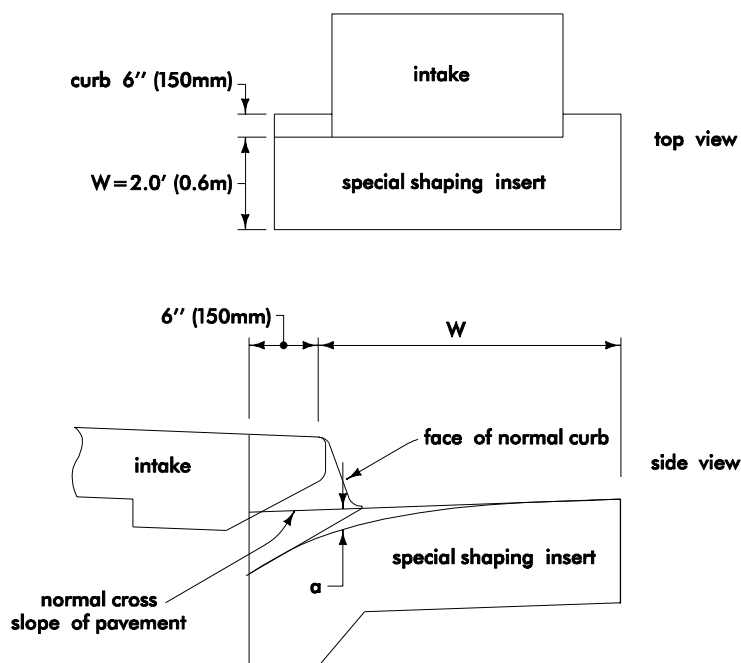


Figure 5: Standard intake and special shaping insert (illustrating “a” and “W”).

If the length of the curb opening (L) is different than the L’s used in Figures 2, 3, and 4, the designer may calculate Q/Q_0 using the following formula:

$$\frac{Q}{Q_0} = \frac{L_{\text{actual}}}{L_{\text{from figure}}}$$

The width of special shaping (W) is the width of the intake insert minus the width of the curb (both measured in feet). For example, the standard insert for an English RA-43 intake is 2.5 feet wide, so $W = 2.5 \text{ feet} - 0.5 \text{ feet (for curb)} = 2.0 \text{ feet}$; the standard insert for a metric RA-43 is 0.8 meters wide so $W = 0.8 \text{ meters} - 0.15 \text{ meters (for curb)} = 0.65 \text{ meters}$.

If calculating the capacity (Q/Q_0) of a non-standard intake and the value of W is different from the value used in the figure (Figure 2, 3, or 4), assume that a 1 foot (0.3 meter) change in W from the W shown in the figure will result in a 25% change in Q/Q_0 from the Q/Q_0 shown in the figure. So if W is increased by 1 foot (0.3 meters), the intake’s Q/Q_0 will increase by 1/4. Similarly, if W is decreased by 1 foot (0.3 meters), Q/Q_0 will decrease by 1/4. This relationship can be inferred from Table 2.

The intake depression (a) is the vertical distance (measured in inches or millimeters) that the intake is depressed below the gutter grade at the face of curb. If the value of “a” is different for an intake than the value shown in the figure (Figure 2, 3, or 4), the effect on Q/Q_0 is similar to the effect for a difference in W. If the value of “a” is increased by 1 inch (25 millimeters), Q/Q_0 increases by 1/4, and if “a” is decreased by 1 inch (25 millimeters), Q/Q_0 decreases by 1/4. This relationship can also be inferred from Table 2 on the next page.

Table 2: Adjustments for variations in depression dimensions (to be used with Figures 2, 3, and 4, and with Figures 7, 8, and 9)

value in figure		actual values for proposed intake		effect on Q/Q_0
English	Metric	English	Metric	
$W = 2', a = 2''$	$W = 0.6 \text{ m}, a = 50 \text{ mm}$	$W = 2', a = 1''$	$W = 0.6 \text{ m}, a = 25 \text{ mm}$	reduce 1/4
$W = 1', a = 1''$	$W = 0.3 \text{ m}, a = 25 \text{ mm}$	$W = 1', a = 2''$	$W = 0.3 \text{ m}, a = 50 \text{ mm}$	increase 1/4
$W = 2', a = 2''$	$W = 0.6 \text{ m}, a = 50 \text{ mm}$	$W = 1', a = 2''$	$W = 0.3 \text{ m}, a = 50 \text{ mm}$	reduce 1/4
$W = 1', a = 1''$	$W = 0.3 \text{ m}, a = 25 \text{ mm}$	$W = 2', a = 1''$	$W = 0.6 \text{ m}, a = 25 \text{ mm}$	increase 1/4
$W = 2', a = 2''$	$W = 0.6 \text{ m}, a = 50 \text{ mm}$	$W = 2', a = 3''$	$W = 0.6 \text{ m}, a = 75 \text{ mm}$	increase 1/4

Intakes Located in Sags

When an intake is located at the low point, or sag, of a vertical curve, the designer must follow special procedures to select the appropriate intake. In such a situation, the gutter grade on both sides of the low point rapidly approaches zero. Thus the procedure given in Section 4A-5 for calculating spread cannot be used because it assumes a constant gutter grade. Additionally, the intake must be designed to pick up 100% of the water flow from both sides of the intake. The designer should therefore follow the three steps given below to decide which intake is appropriate.

Step 1 is to decide whether the intake operates as an orifice (intake submerged) or a weir (intake not submerged) for the design storm (assuming the intake is a curb opening type). Figure 6 on the next page is used to make this decision. On the left side of Figure 6, find the total gutter flow at the intake (total Q from both directions). From Q , go horizontally to intercept the length of the intake opening (L_i). Then go down to read the height of the water, h_m , at the bottom of the chart. If the water is over 0.5 feet (0.15 meters) deep, the intake opening is submerged and the intake is operating as an orifice.



If the curb is submerged, the maximum spread has been exceeded on primary highways, and it will be necessary to relocate the intake or add intakes to the system.

Step 2 is to check the ponding of water at the intake due to the limit on the intake's capacity. Figures 7, 8, and 9 are used for this purpose (note that these figures are designed only for when the intake operates as a weir). Normally Figure 7 will be used because it has $W = 2$ feet (0.6 meters) and $a = 3$ inches (75 millimeters); Figures 8 and 9 are only for non-standard intakes. Using the figure appropriate to the intake, find the value of Q (total from both directions) on the left side of the figure. Go horizontally to the appropriate length of opening (L) and then down to read the water depth (d). The spread can then be calculated from $w = (Z)(d)$, where $Z = 1/S_x$. Adjust for values of " a " and W not shown in the figures using Table 2, as with the adjustments for continuous grades. If the intake's opening is different than shown in the figures, interpolate between two curves in the appropriate figure. Note that Q 's from both directions must be added together to get Q_i .

Step 3 is to check the spread caused by the longitudinal grade approaching zero near the intake. Use Figure 10 and the Q from each direction independently. The figure will show the spread at the curb (for each side of the intake) when the longitudinal slope is 0.002 (the minimum slope required to carry water in the gutter just before reaching the intake).

When allowable encroachment is exceeded (see Table 1, Section 4A-5), either by ponding or due to the leveling of the gutter grade, additional intakes must be added or existing intakes must be altered or relocated to reduce the Q approaching the intake. Often these are good locations for flanking intakes (see Section 4A-3).

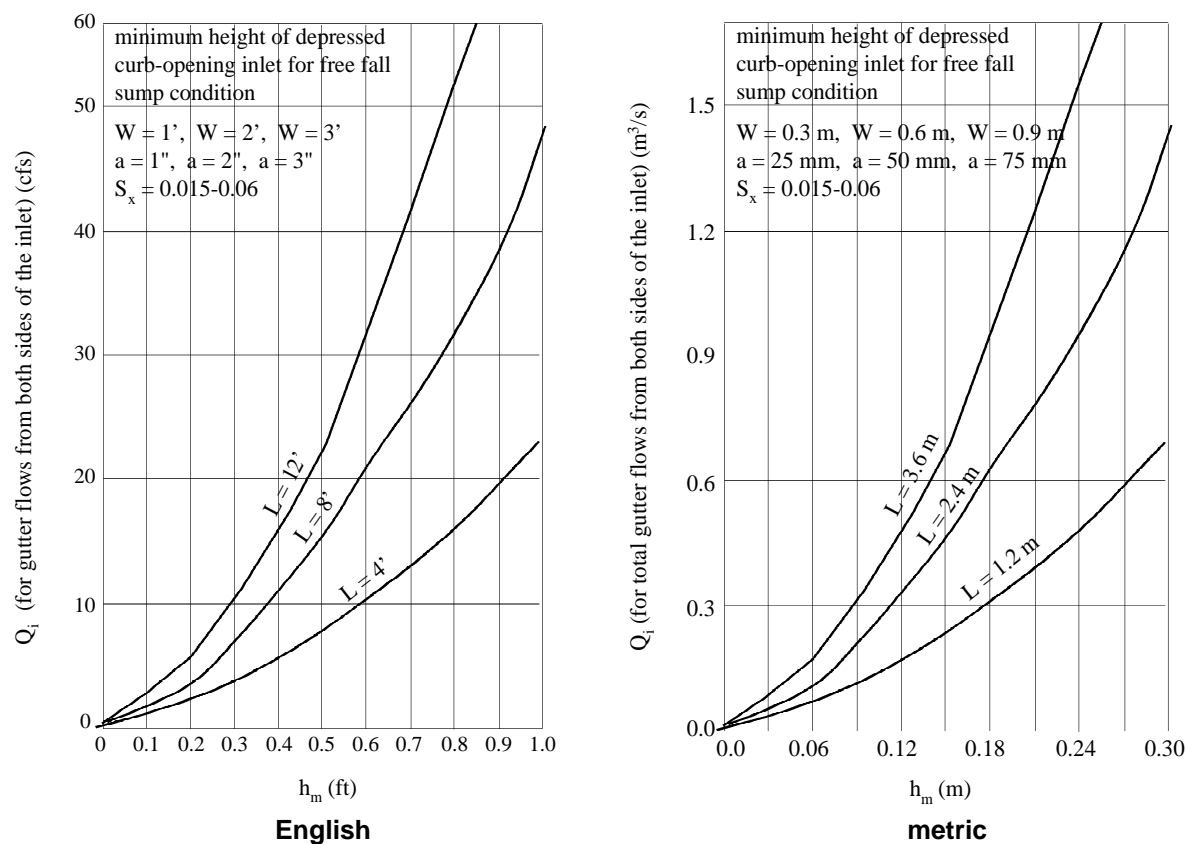


Figure 6: Height of curb opening needed for intake to operate as a weir.³

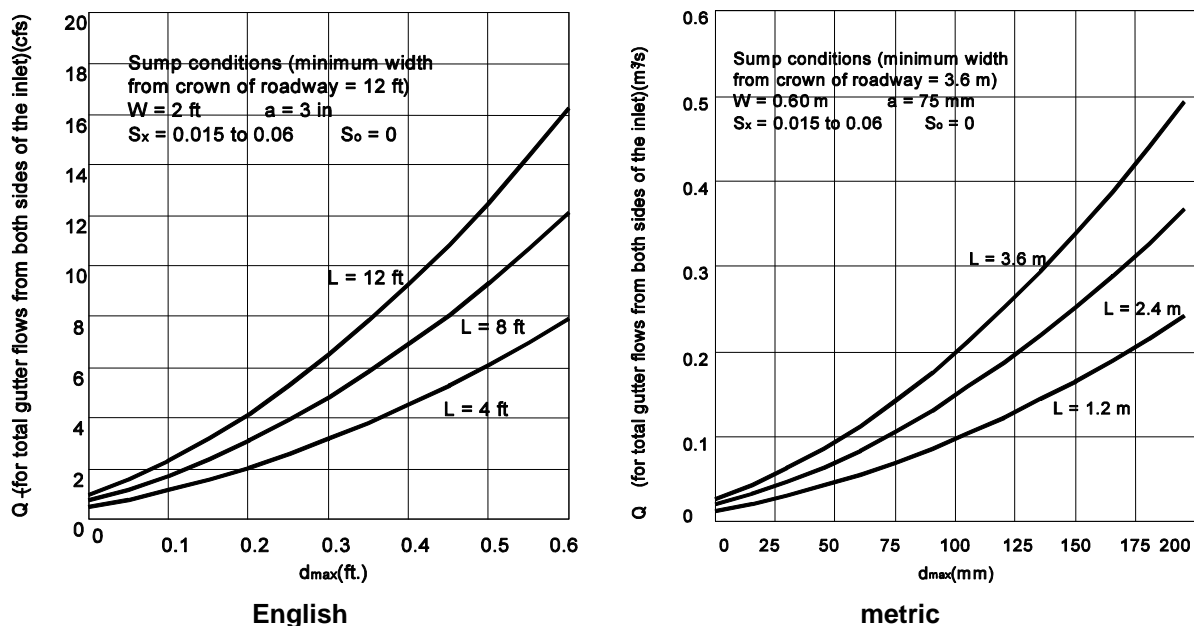


Figure 7: Depth of ponding when intake operates as a weir.³

³ FHWA, *Design of Urban Highway Drainage, State of the Art* (August 1979).

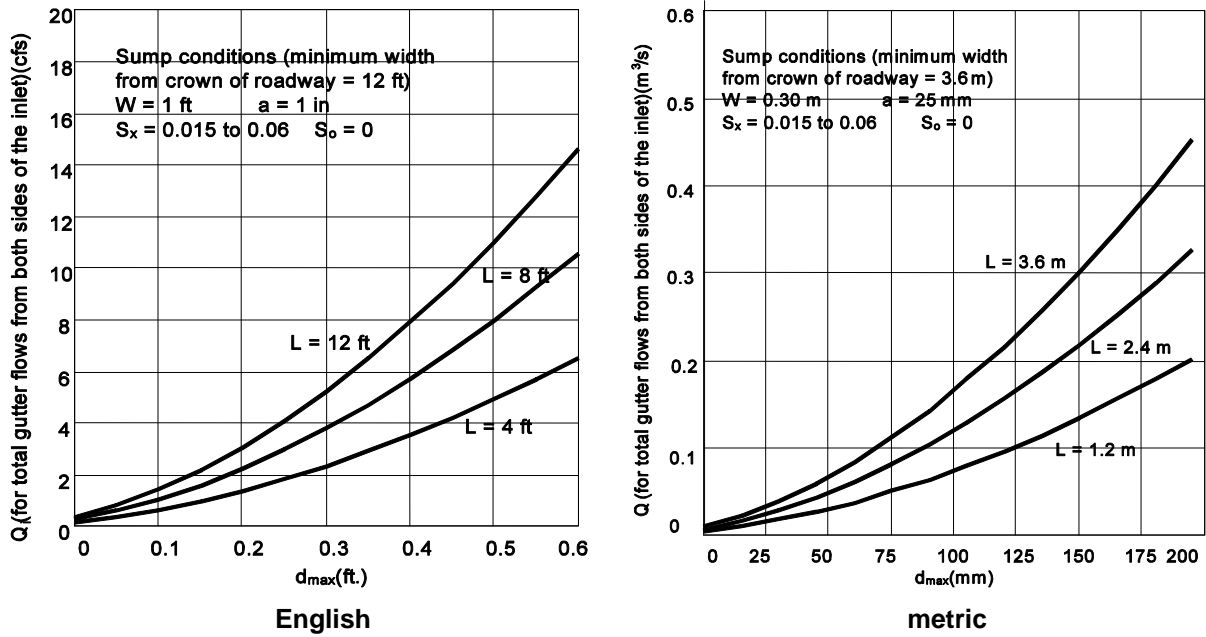


Figure 8: Depth of ponding when intake operates as a weir.³

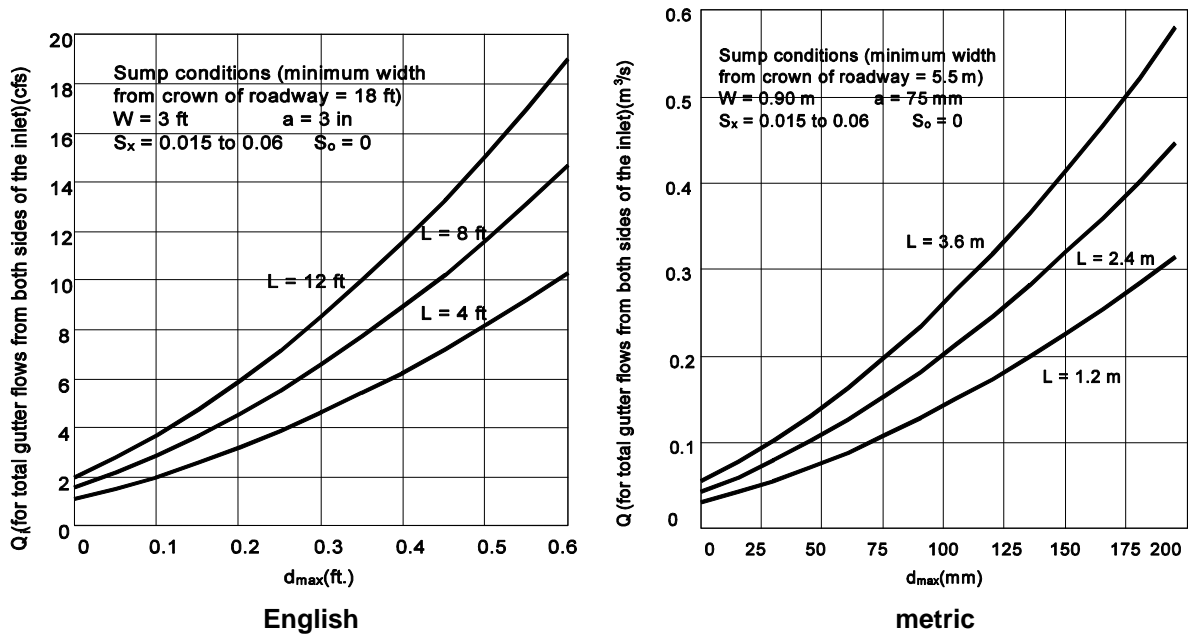


Figure 9: Depth of ponding when intake operates as a weir.³

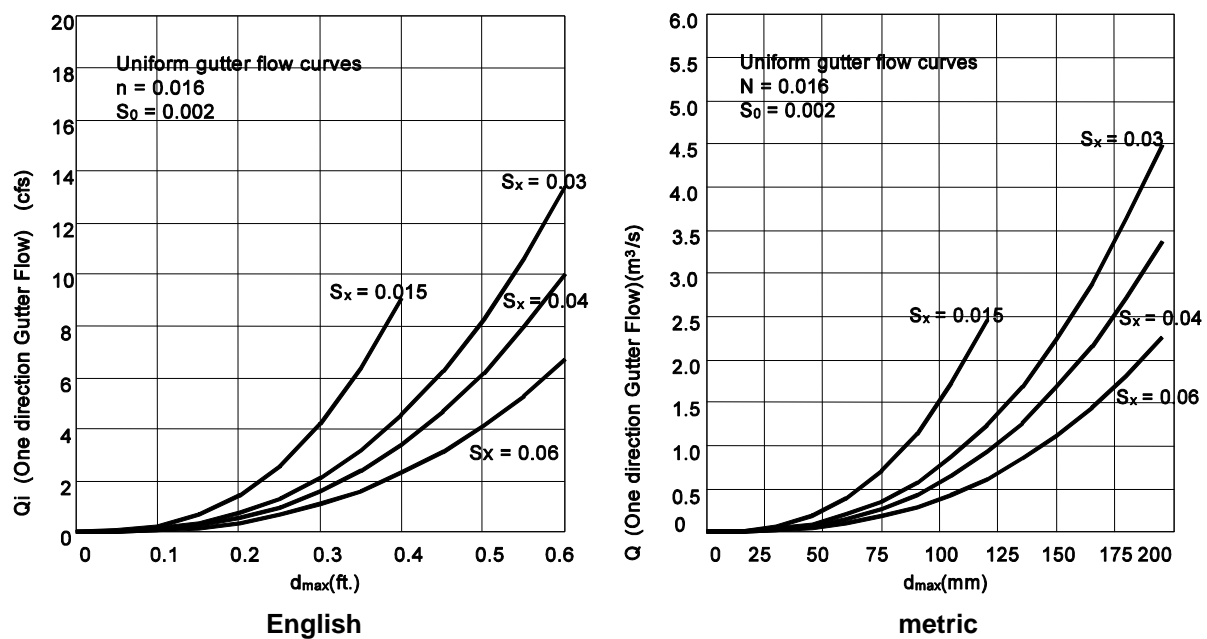


Figure 10: Depth of flow at intake where gutter grade is minimum.³